Description

This non-isolated buck converter provides a fixed output of 14V at 130mA for BMS applications. It operates over an input voltage range of 18Vdc – 144Vdc after a startup greater than 23V. Operating in Discontinuous Conduction Mode (DCM), this converter utilizes the UCC28730 controller, which is referenced to the switch node. It offers high efficiency and low cost in a compact form factor.

Figure 1-1. This figure shows the top of the board on the top, and the bottom of the board on the bottom.
1 Test Prerequisites

1.1 Voltage and Current Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>18 V–144 V, after &gt; 23-V startup</td>
</tr>
<tr>
<td>Output voltage and current</td>
<td>14 V ±1 V, 130 mA maximum</td>
</tr>
<tr>
<td>Switching frequency</td>
<td>Variable, 83 KHz maximum</td>
</tr>
<tr>
<td>Isolation</td>
<td>No</td>
</tr>
<tr>
<td>Controller features</td>
<td>Valley switching, frequency dithering, 700-V startup switch, overcurrent and overvoltage protection</td>
</tr>
</tbody>
</table>

1.2 Required Equipment

- Resistive load (resistor decade box), 2 W minimum
- Power supply, adjustable, 0 V–150 V and 0.25 A minimum
- Oscilloscope and probes
- Digital multimeter
2 Testing and Results

2.1 Thermal Images

This thermal image shows the operating temperature of the top side of the board with 100 V\textsubscript{DC} input and 14 V at 130-mA output at room temperature and no air flow.

![Top-Side Thermal Image, 100-V\textsubscript{DC} Input, 14 V at 130-mA Output]

This thermal image shows the operating temperature of the bottom side of the board with 100-V\textsubscript{DC} input and 14 V at 130-mA output at room temperature and no air flow.

![Bottom-Side Thermal Image, 100 V\textsubscript{DC} Input, 14 V at 130-mA Output]
This thermal image shows the operating temperature of the top side of the board with 30-V$_{DC}$ input and 14 V at 130-mA output at room temperature and no air flow.

![Top-Side Thermal Image](image)

Figure 2-3. Top-Side Thermal Image, 30-V$_{DC}$ Input, 14 V at 130-mA Output

This thermal image shows the operating temperature of the bottom side of the board with 30-V$_{DC}$ input and 14 V at 130-mA output at room temperature and no air flow.

![Bottom-Side Thermal Image](image)

Figure 2-4. Bottom-Side Thermal Image, 30 V$_{DC}$ Input, 14 V at 130-mA Output
2.2 Efficiency and Power Dissipation graphs

The following figure displays the efficiency and power dissipation of the converter at input voltages of 30 $V_{\text{DC}}$, 60 $V_{\text{DC}}$, 90 $V_{\text{DC}}$ and 120 $V_{\text{DC}}$.

![PMP22487 Efficiency, $V_{\text{OUT}} = 14\,\text{V}$](image)

*Figure 2-5. PMP22487 Efficiency, $V_{\text{OUT}} = 14\,\text{V}$*
2.3 Efficiency and Power Dissipation Data

Efficiency data is shown in the following table.

![Table showing efficiency and power dissipation data for different input voltages]

*Figure 2-6. Efficiency data for Vin = 30V, 60V*
<table>
<thead>
<tr>
<th>Vin (V)</th>
<th>lin</th>
<th>Vout (V)</th>
<th>Iout1 (A)</th>
<th>Pout (W)</th>
<th>Pin (W)</th>
<th>Efficiency (%)</th>
<th>Vin3 = 90Vdc</th>
<th>Pdiss3 (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90.1040</td>
<td>0.0031</td>
<td>14.026</td>
<td>0.010080</td>
<td>0.141</td>
<td>0.278</td>
<td>50.9%</td>
<td>0.136</td>
<td></td>
</tr>
<tr>
<td>90.1000</td>
<td>0.0049</td>
<td>14.014</td>
<td>0.020070</td>
<td>0.281</td>
<td>0.441</td>
<td>63.8%</td>
<td>0.159</td>
<td></td>
</tr>
<tr>
<td>90.0970</td>
<td>0.0067</td>
<td>13.995</td>
<td>0.030000</td>
<td>0.420</td>
<td>0.600</td>
<td>70.0%</td>
<td>0.180</td>
<td></td>
</tr>
<tr>
<td>90.0940</td>
<td>0.0084</td>
<td>13.982</td>
<td>0.040010</td>
<td>0.559</td>
<td>0.759</td>
<td>73.7%</td>
<td>0.200</td>
<td></td>
</tr>
<tr>
<td>90.0400</td>
<td>0.0104</td>
<td>13.977</td>
<td>0.049000</td>
<td>0.697</td>
<td>0.937</td>
<td>74.4%</td>
<td>0.240</td>
<td></td>
</tr>
<tr>
<td>90.1890</td>
<td>0.0122</td>
<td>13.967</td>
<td>0.060000</td>
<td>0.838</td>
<td>1.098</td>
<td>76.4%</td>
<td>0.250</td>
<td></td>
</tr>
<tr>
<td>90.0840</td>
<td>0.0139</td>
<td>13.968</td>
<td>0.069000</td>
<td>0.976</td>
<td>1.255</td>
<td>77.8%</td>
<td>0.279</td>
<td></td>
</tr>
<tr>
<td>90.0300</td>
<td>0.0158</td>
<td>13.962</td>
<td>0.080300</td>
<td>1.121</td>
<td>1.421</td>
<td>78.9%</td>
<td>0.300</td>
<td></td>
</tr>
<tr>
<td>90.0270</td>
<td>0.0176</td>
<td>13.967</td>
<td>0.090300</td>
<td>1.261</td>
<td>1.584</td>
<td>79.6%</td>
<td>0.322</td>
<td></td>
</tr>
<tr>
<td>90.0730</td>
<td>0.0194</td>
<td>13.962</td>
<td>0.100000</td>
<td>1.396</td>
<td>1.744</td>
<td>80.0%</td>
<td>0.348</td>
<td></td>
</tr>
<tr>
<td>90.0200</td>
<td>0.0212</td>
<td>13.968</td>
<td>0.110200</td>
<td>1.539</td>
<td>1.912</td>
<td>80.5%</td>
<td>0.373</td>
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<tr>
<td>90.1140</td>
<td>0.0230</td>
<td>13.964</td>
<td>0.119800</td>
<td>1.673</td>
<td>2.069</td>
<td>80.9%</td>
<td>0.396</td>
<td></td>
</tr>
<tr>
<td>90.0120</td>
<td>0.0251</td>
<td>13.976</td>
<td>0.131000</td>
<td>1.831</td>
<td>2.256</td>
<td>81.2%</td>
<td>0.425</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Vin (V)</th>
<th>lin</th>
<th>Vout (V)</th>
<th>Iout1 (A)</th>
<th>Pout (W)</th>
<th>Pin (W)</th>
<th>Efficiency (%)</th>
<th>Vin4 = 120Vdc</th>
<th>Pdiss4 (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120.1880</td>
<td>0.0025</td>
<td>14.010</td>
<td>0.010070</td>
<td>0.141</td>
<td>0.302</td>
<td>46.8%</td>
<td>0.161</td>
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<tr>
<td>120.1860</td>
<td>0.0039</td>
<td>14.008</td>
<td>0.020060</td>
<td>0.281</td>
<td>0.470</td>
<td>59.8%</td>
<td>0.189</td>
<td></td>
</tr>
<tr>
<td>120.0850</td>
<td>0.0053</td>
<td>13.990</td>
<td>0.029990</td>
<td>0.420</td>
<td>0.632</td>
<td>66.4%</td>
<td>0.212</td>
<td></td>
</tr>
<tr>
<td>120.0820</td>
<td>0.0066</td>
<td>13.981</td>
<td>0.040010</td>
<td>0.559</td>
<td>0.793</td>
<td>70.6%</td>
<td>0.233</td>
<td></td>
</tr>
<tr>
<td>120.0800</td>
<td>0.0081</td>
<td>13.972</td>
<td>0.049900</td>
<td>0.697</td>
<td>0.973</td>
<td>71.7%</td>
<td>0.275</td>
<td></td>
</tr>
<tr>
<td>120.0770</td>
<td>0.0094</td>
<td>13.965</td>
<td>0.060000</td>
<td>0.838</td>
<td>1.134</td>
<td>73.9%</td>
<td>0.296</td>
<td></td>
</tr>
<tr>
<td>120.0750</td>
<td>0.0108</td>
<td>13.963</td>
<td>0.069900</td>
<td>0.976</td>
<td>1.291</td>
<td>75.6%</td>
<td>0.315</td>
<td></td>
</tr>
<tr>
<td>120.0720</td>
<td>0.0122</td>
<td>13.961</td>
<td>0.080300</td>
<td>1.121</td>
<td>1.462</td>
<td>76.7%</td>
<td>0.341</td>
<td></td>
</tr>
<tr>
<td>120.0170</td>
<td>0.0136</td>
<td>13.963</td>
<td>0.090200</td>
<td>1.259</td>
<td>1.629</td>
<td>77.3%</td>
<td>0.359</td>
<td></td>
</tr>
<tr>
<td>120.0140</td>
<td>0.0149</td>
<td>13.962</td>
<td>0.100000</td>
<td>1.396</td>
<td>1.794</td>
<td>77.8%</td>
<td>0.397</td>
<td></td>
</tr>
<tr>
<td>120.0640</td>
<td>0.0164</td>
<td>13.964</td>
<td>0.110200</td>
<td>1.539</td>
<td>1.965</td>
<td>78.3%</td>
<td>0.426</td>
<td></td>
</tr>
<tr>
<td>120.0610</td>
<td>0.0177</td>
<td>13.964</td>
<td>0.119800</td>
<td>1.673</td>
<td>2.127</td>
<td>78.7%</td>
<td>0.454</td>
<td></td>
</tr>
<tr>
<td>120.1070</td>
<td>0.0193</td>
<td>13.972</td>
<td>0.131000</td>
<td>1.830</td>
<td>2.316</td>
<td>79.0%</td>
<td>0.485</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2-7. Efficiency data for Vin =90V, 120V
2.4 Voltage Regulation

The following graph displays the measured output voltage at input voltages of 18 V<sub>DC</sub> and 144 V<sub>DC</sub>.

![PMP22487 Voltage Regulation](image)

Figure 2-8. PMP22487 Voltage Regulation
3 Waveforms

3.1 Start-up

The following figure shows output voltage startup waveform (BLUE) after the application of 30-V input (YELLOW) with the 14-V output loaded to 130 mA.

![Figure 3-1. Output Voltage Start-up Waveform (V_{IN}: 5 V/div, V_{OUT}: 5 V/div, 50 ms/div)](image)

The following figure shows the output voltage startup waveform (BLUE) after the application of 30-V input (YELLOW) with the 14-V output loaded to 0 mA.

![Figure 3-2. Output Voltage Start-up Waveform (V_{IN}: 5 V/div, V_{OUT}: 5 V/div, 50 ms/div)](image)
The following figure shows the output voltage startup waveform (BLUE) after the application of 60-V input (YELLOW) with the 14-V output loaded to 130 mA.

![Waveform Image](image1)

**Figure 3-3. Output Voltage Start-up Waveform (V\textsubscript{IN}: 20 V/div, V\textsubscript{OUT}: 5 V/div, 50 ms/div)**

The following figure shows the output voltage startup waveform (BLUE) after the application of 60-V input (YELLOW) with the 14-V output loaded to 0 mA.

![Waveform Image](image2)

**Figure 3-4. Output Voltage Start-up Waveform (V\textsubscript{IN}: 20 V/div, V\textsubscript{OUT}: 5 V/div, 50 ms/div)**
The following figure shows the output voltage startup waveform (BLUE) after the application of 120-V input (YELLOW) with the 14-V output loaded to 130 mA.

Figure 3-5. Output Voltage Start-up Waveform ($V_{IN}$: 20 V/div, $V_{OUT}$: 5 V/div, 50 ms/div)

The following figure shows the output voltage startup waveform (BLUE) after the application of 120-V input (YELLOW) with the 14-V output loaded to 0 mA.

Figure 3-6. Output Voltage Start-up Waveform ($V_{IN}$: 20 V/div, $V_{OUT}$: 5 V/div, 50 ms/div)
### 3.2 Switch Node

The following image shows the FET switch node voltage (YELLOW) at TP3 and the input voltage (BLUE). The input voltage is 18 V and the 14-V output is loaded to 130 mA.

![Waveform Image](image1)

**Figure 3-7. FET Switch Node Voltage (Vsnode: 5 V/div, V<sub>IN</sub>: 5 V/div, 10 μs/div)**

The following image (scope persistence on) shows the FET switch node voltage (YELLOW) at TP3 and the input voltage (BLUE). The input voltage is 18 V and the 14-V output is loaded to 130 mA. This shows the effects of valley switching and frequency dithering on the switch node waveform.

![Waveform Image](image2)

**Figure 3-8. FET Switch Node Voltage (Vsnode: 5 V/div, V<sub>IN</sub>: 5 V/div, 10 μs/div)**
The following image shows the FET switch node voltage (YELLOW) at TP3 and the input voltage (BLUE). The input voltage is 18 V and the 14-V output is loaded to 0 mA.

![Waveform Image](image1)

**Figure 3-9. FET Switch Node Voltage (Vsnode: 5 V/div, V\_IN: 5 V/div, 100 μs/div)**

The following image shows the FET switch node voltage (YELLOW) at TP3 and the input voltage (BLUE). The input voltage is 80 V and the 14-V output is loaded to 130 mA.

![Waveform Image](image2)

**Figure 3-10. FET Switch Node Voltage (Vsnode: 20 V/div, V\_IN: 20 V/div, 10 μs/div)**
The following image shows the FET switch node voltage (YELLOW) at TP3 and the input voltage (BLUE). The input voltage is 80 V and the 14-V output is loaded to 0 mA.

Figure 3-11. FET Switch Node Voltage (Vsnode: 20 V/div, $V_{IN}$: 20 V/div, 50 μs/div)

The following image shows the FET switch node voltage (YELLOW) at TP3 and the input voltage (BLUE). The input voltage is 144 V and the 14-V output is loaded to 130 mA.

Figure 3-12. FET Switch Node Voltage (Vsnode: 50 V/div, $V_{IN}$: 50 V/div, 10 μs/div)
The following image shows the FET switch node voltage (YELLOW) at TP3 and the input voltage (BLUE). The input voltage is 144 V and the 14-V output is loaded to 0 mA.

![Figure 3-13. FET Switch Node Voltage (Vsnode: 50 V/div, V\text{IN}: 50 V/div, 50 \mu s/div)](image)

The following image shows the switching voltages on each side of C1. The waveforms show the switch node voltage at TP3 (YELLOW) and D1 cathode voltage (BLUE). The input voltage is 50 V and the 14-V output is loaded to 130 mA.

![Figure 3-14. Switching Voltages (Vsnode: 10 V/div, D1-Cathode: 10 V/div, 10 \mu s/div)](image)
The following image shows the switching voltages on each side of resistor divider R1/R2. The waveforms show the switch node voltage at TP3 (YELLOW) and the voltage at R1 (side connected to D2) (BLUE). The input voltage is 50 V and the 14-V output is loaded to 130 mA.

Figure 3-15. Switching Voltages (Vsnode: 10 V/div, D1-Cathode: 10 V/div, 10 μs/div)
### 3.3 Output Voltage Ripple

The following image illustrates the output ripple voltage (AC coupled). The input voltage is 18 V and the 14-V output is loaded to 130 mA.

![Figure 3-16. Output Voltage Ripple (AC Coupled) (V\textsubscript{OUT}: 50 mV/div, 50 μs/div)](image)

The following image illustrates the output ripple voltage (AC coupled). The input voltage is 30 V and the 14-V output is loaded to 130 mA.

![Figure 3-17. Output Voltage Ripple (AC Coupled) (V\textsubscript{OUT}: 50 mV/div, 50 μs/div)](image)
The following image illustrates the output ripple voltage (AC coupled). The input voltage is 120 V and the 14-V output is loaded to 130 mA.

Figure 3-18. Output Voltage Ripple (AC Coupled) ($V_{OUT}$: 50 mV/div, 50 μs/div)
3.4 Load Transients

The following image illustrates the 14-V output voltage (AC coupled) when the load current is stepped between 80 mA and 130 mA (50-mA load step), $V_{IN} = 30$ V.

![Figure 3-19. Load Transient, 14-V Output Voltage (AC Coupled) ($V_{OUT}$: 100 mV/div, $I_{OUT}$: 50 mA/div, 1 ms/div)](image)

The following image illustrates the 14-V output voltage (AC coupled) when the load current is stepped between 130 mA and 80 mA (50-mA load step), $V_{IN} = 30$ V.

![Figure 3-20. Load Transient, 14-V Output Voltage (AC Coupled) ($V_{OUT}$: 100 mV/div, $I_{OUT}$: 50 mA/div, 1 ms/div)](image)
The following image illustrates the 14-V output voltage (AC coupled) when the load current is stepped between 80 mA and 130 mA (50-mA load step), $V_{IN} = 120$ V.

![Figure 3-21. Load Transient, 14-V Output Voltage (AC Coupled) ($V_{OUT}$: 100 mV/div, $I_{OUT}$: 50 mA/div, 1 ms/div)](image)

The following image illustrates the 14-V output voltage (AC coupled) when the load current is stepped between 130 mA and 80 mA (50-mA load step), $V_{IN} = 120$ V.

![Figure 3-22. Load Transient, 14-V Output Voltage (AC Coupled) ($V_{OUT}$: 100 mV/div, $I_{OUT}$: 50 mA/div, 1 ms/div)](image)
3.5 Short-Circuit Recovery Response

The following image illustrates the output voltage (YELLOW) recover from a hard short to ground and the output load current (GREEN), $V_{IN} = 30$ V and $V_{OUT}$ is 14 V at 130 mA.

![Waveform](image1)

**Figure 3-23. Short-Circuit Recovery ($V_{OUT}$: 5 V/div, $I_{OUT}$: 200 mA/div, 50 ms/div)**

The following image illustrates the output voltage (YELLOW) recover from a hard short to ground and the output load current (GREEN), $V_{IN} = 120$ V and $V_{OUT}$ is 14 V at 130 mA.

![Waveform](image2)

**Figure 3-24. Short-Circuit Recovery ($V_{OUT}$: 5 V/div, $I_{OUT}$: 200 mA/div, 50 ms/div)**
3.6 Input Voltage Transient Response

The following image shows the 14-V output voltage (AC coupled) (YELLOW) when the input voltage transitions from 120 V to 30 V (BLUE), 14 V is loaded to 130 mA.

Figure 3-25. Input Voltage Transient Response ($V_{OUT}$: 100 mV/div, $V_{IN}$: 200 mA/div, 50 ms/div)

The following image shows the 14-V output voltage (AC coupled) (YELLOW) when the input voltage transitions from 30 V to 120 V (BLUE), 14 V is loaded to 130 mA.

Figure 3-26. Input Voltage Transient Response ($V_{OUT}$: 5 V/div, $I_{OUT}$: 200 mA/div, 50 ms/div)
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